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Robot-assisted Partial Nephrectomy in Patients with Baseline Chronic Kidney Disease: A Multi-institutional Propensity Score–Matched Analysis

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Abstract

Background: Robot-assisted partial nephrectomy (RPN) in the setting of chronic kidney disease (CKD) presents additional challenges for the preservation of renal function.
Objective: To evaluate functional outcomes of RPN in patients with CKD relative to patients undergoing RPN without baseline CKD.
Design, setting, and participants: A total of 1197 consecutive patients who underwent RPN at five academic institutions between 2007 and 2012 were identified for this descriptive study. A total of 172 patients who underwent RPN with preexisting CKD (estimated glomerular filtration rate [eGFR] of 15–60 ml/min per 1.73 m^2) were identified. Perioperative results of 121 patients were compared against propensity score–matched controls without CKD (eGFR $\geq$60 ml/min per 1.73 m^2).
Intervention: RPN in patients with or without baseline CKD.
Outcome measurements and statistical analysis: Descriptive statistics and propensity score–matched operative and functional outcomes.
Results and limitations: After propensity score matching, patients with baseline CKD had a lower percentage eGFR decrease at first follow-up (−5.1 vs −10.9), which remained significant at a mean follow-up of 12.6 mo (−2.8 vs −9.1, $p < 0.05$), and they had less CKD upstaging (11.8% vs 33.1%). CKD patients were less likely to be discharged in the first two postoperative days (39.7% vs 56.2%, $p = 0.006$) and had a higher rate of surgical complications (21.5% vs 10.7%, $p = 0.007$). The retrospective analysis was the main limitation of this study.
Conclusions: RPN in patients with baseline CKD is associated with a smaller decrease in renal function compared with patients without baseline CKD, but a higher risk of surgical complications and a longer hospital stay.

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1. Introduction

Partial nephrectomy (PN) is considered the standard-of-care treatment of pT1 renal masses and is associated with a lower risk of chronic kidney disease (CKD), cardiovascular adverse events, and death relative to radical nephrectomy [1–3]. Current guidelines support the use of nephron-sparing surgery in the treatment of small renal masses whenever technically feasible [4,5]. Robot-assisted partial nephrectomy (RPN) is a minimally invasive alternative to open PN [6,7].

CKD represents a significant public health concern, with a prevalence of approximately 11.5% [8]. In patients with CKD, the use of nephron-sparing surgery is important for maximal preservation of renal function to help prevent end-stage renal disease [9]. Data are limited about functional outcomes after minimally invasive PN in patients with CKD. A single-institution study examining RPN in patients with CKD showed a lower decrease in renal function but a higher risk of complications compared with patients without CKD [10]. We sought to validate these findings of perioperative and functional outcomes after RPN in CKD patients using a large multi-institutional cohort of patients and propensity score–matched analysis.

2. Patients and methods

2.1. Patient population

Perioperative data from 1197 consecutive RPNs performed at five academic medical centers between May 2007 and October 2012 were assessed for inclusion in this descriptive study. Data were prospectively collected and retrospectively analyzed through an investigational review board–approved system, which includes approved between-institution sharing protocols and appropriate deidentification of patients for privacy protection. The estimated glomerular filtration rate (eGFR) was calculated using the Modification of Diet in Renal Disease (MDRD) formula [11], and patients were categorized according to CKD stage (stages 1–5) defined by the National Kidney Foundation. The study cohort consisted of patients with an eGFR of $<$60 ml/min per 1.73 m^2 (CKD stage $\geq$3). Controls had a preoperative eGFR of $\geq$60 ml/min per 1.73 m^2.

Patient demographics and perioperative outcomes were analyzed, including age, gender, race, body mass index (BMI), American Society of Anesthesiologists (ASA) score, Charlson Comorbidity Index (CCI), RENAL nephrometry score, preoperative eGFR, solitary kidney status, warm ischemia time (WIT), and number of tumors (Table 1). Postoperative outcomes included percentage change in eGFR at first follow-up (1–6 mo) and last follow-up, length of stay, complications (classified according to the Clavien grading system), margin status, and cancer recurrence. The timing of the first postoperative visit for eGFR calculation differed by center protocol (ie, 1, 3, or 6 mo), so the first follow-up visit during a 1–6-mo interval was used for the first follow-up eGFR calculation. The percentage change in eGFR was calculated according to the following formula: (preoperative eGFR – postoperative eGFR)/preoperative eGFR. This formula weighted the eGFR postoperative decrease according to the baseline eGFR by dividing the difference between the preoperative and postoperative eGFRs by the baseline eGFR. Follow-up protocols varied by center but generally included computed tomography scanning or magnetic resonance imaging at intervals of 6–12 mo. *Recurrence* was defined as radiographic evidence of local or distant recurrence on follow-up imaging.

2.2. Surgical technique

All RPN procedures were performed with the da Vinci Surgical System (Intuitive Surgical, Inc., Sunnyvale, CA, USA) by one of five experienced high-volume surgeons ($>$200 cases for all centers) using a technique as previously described [12–14]. Typically, there was one camera port, two ports for robotic instruments, and one or two ports for the assistant, with an optional port for the third robotic arm [14]. The renal artery was routinely localized and dissected. After the Gerota fascia was dissected, the tumor was identified and demarcated with the assistance of intraoperative ultrasonography. Tumor excision was performed to incorporate a thin margin of normal parenchyma when possible. Following tumor resection, an inner parenchymal layer sutured reconstruction was performed, followed by capsular sutures for approximation of the renal defect.

2.3. Statistical analysis

Demographic and perioperative data were analyzed using descriptive statistics. Frequencies were used for continuous variables, and proportions were used for categorical variables. The significance of differences in these estimates was analyzed using two-sided t tests for continuous variables and the Fisher exact or χ^2 test for categorical variables.

The propensity score was built by way of a multivariable logistic regression model considering the following variables: age, gender, race, BMI, ASA score, CCI, multiple tumors, solitary kidney, tumor size, and RENAL nephrometry score. Age and BMI were considered in a continuous fashion. Patients were excluded from the matched analysis if they were missing any demographic, eGFR, WIT, or nephrometry score data. The propensity score was then used to generate clusters in which one case was matched to multiple controls as long as their probability of having a preoperative eGFR $<$60 (ie, propensity score) did not differ by $>$0.1. Propensity score matching was considered for 172 CKD patients and 1025 control patients. After excluding patients with missing perioperative GFR data, 121 CKD cases remained, which were propensity score matched at a 3-to-1 ratio to controls (n = 363). We chose a 3-to-1 ratio to maximize statistical power while maintaining optimal distribution of covariates in the propensity score match. A sensitivity analysis that included WIT as a covariate showed equivalent findings and was excluded from the analysis. Propensity score matching was performed using the MatchIt package in R, implementing the suggestions of Ho and colleagues for improving parametric statistical models by preprocessing data with nonparametric matching methods [15].

All tests were two-sided, with a statistical significance set at $p < 0.05$. Analyses were conducted using the R statistical package v.2.13.1 (R Foundation for Statistical Computing, Vienna, Austria).

3. Results

Demographic and preoperative data before and after propensity score matching regarding the CKD and control groups are presented in Table 1. The study included 172 CKD patients and 1025 control patients. Following propensity score matching, there were 121 CKD cases and 363 controls. The mean preoperative eGFR in the 172 CKD patients was 48.05 ml/min per 1.73 m^2 (standard deviation: $\pm$9.94), compared with 89.16 ml/min per 1.73 m^2 (standard deviation: $\pm$23.40) for the 1025 patients in the control group. Patients in the CKD group were more likely to be $>$65 yr than patients in the control group (61% vs 29.5%), with comorbidities reflected in a higher ASA score and CCI ($p < 0.001$). There was no statistically significant difference in the RENAL nephrometry score of tumors between groups. Patients in